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Comparison on the Soil Seed Bank of Exclosures and free Grazing Areas for Restoration in Tigray Region, N. Ethiopia.

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Abstract:

An investigation of the seed composition of seed banks is ecologically important in predicting the initial composition of the pioneer vegetation in an area, particularly on exposed or cleared sites. This study was initiated with the objectives of gaining more knowledge on the role of seed banks in stimulating vegetation regeneration leading to natural dry evergreen afromontane forest restoration, by analyzing their species composition and abundance and further investigates the difference on soil seed bank in exclosures and the adjacent free grazing areas. Soil seed bank density, diversity, vertical and horizontal distribution and composition were assessed by collecting 360 soil samples. The total numbers of species recovered from the soil samples collected in the study area were 47 for the exclosure and 39 for the free grazing area and totally 62 species. The total seed density in the upper nine centimeters both from seedling emergence and seed counting method was 1868 seeds m^{-2} for exclosures and 1431 seeds m^{-2} for free grazing areas. The similarity between the soil seed bank and above-ground flora was also low for exclosures *Sj* value 0.29 and average for free grazing area *Sj* value 0.51. But the herbs similarities was high showing 0.75 and 0.78 similarities in exclosures and free grazing respectively. Similarity between the soil seed banks and aboveground flora was very low implying that the role of soil seed banks in the regeneration is low and dispersal of seeds from the adjacent forest areas play an important role in the process. These results support the idea that assisted natural regeneration can promote the regeneration of species and increase plant biodiversity in the area, if seed sources are available in the area or nearby sites of the restoration areas.

Keywords: Exclosure, Free grazing area; Soil seed bank; Tigray (Ethiopia).

Introduction

Importance of Soil Seed Bank for Regeneration of Exclosures

The seed banks found in different environments represent a record of past as well as present vegetation growing in the area and nearby. If an existing vegetation stand is destroyed by various causes, the seed bank will immediately serve as a source from which new vegetation arises (Harper, 1977). In addition their significance in the regeneration of lost vegetation, seed banks are also essential in the rehabilitation of a degraded land.

An investigation of the seed composition of seed banks is ecologically important in predicting the initial composition of the pioneer vegetation in an area, particularly on exposed or cleared sites. The information on the relative abundance of recently recruited species and the potential distribution of each species can also be obtained from careful investigation of the composition of seed banks (Van der Valk and Pederson, 1989).

In forest management, natural seed banks as seed sources are valuable in tropical forestry (Fenner, 1985). Soil seed banks serve as a source of regeneration of plant communities. Seed banks have been exploited to manage the composition and structure of existing vegetation and to restore or establish native vegetation (Van der Valk and Pederson, 1989).

Knowledge about the dynamics of soil seed banks and seedling populations provides clues about the potential of a plant community to regenerate after disturbance (Demel, 1996). The seed banks hence reflect the history of the vegetation and have the potential to contribute to its future through regeneration. For a good understanding of a natural vegetation in any plant community gathering information on the quality and quantity of seed rain, germination requirement of seeds, longevity of seeds in the soil, losses of seeds to predation and deterioration, presence and absence of persistent soil seed banks or seedling banks, and sources of regrowth after disturbances, etc (Demel, 1996). One of the most common methods of reproduction in most plant communities is, therefore, regeneration from seeds of the soil seed bank (Fenner, 1985).

In areas where there is a frequent disturbance, the soil seed banks are the main establishing factor that serves to ensure species survival and success. The regeneration of plant communities from seed banks depends on the viability of the seed and on the frequency of 'safe sites', not only on the viability of seeds (Harper, 1977). A 'Safe site' is considered as that zone in which a seed may find itself and which provides the resources which are consumed in the course of germination, the conditions required for proceeding germination process and the stimuli required for breaking of seed dormancy. Furthermore, a safe site is one from which specific hazards are absent such as predators, competitors, toxic soil constituents, and pathogens.

Generally, the regeneration of plant communities depends on conditions, which are localized to the environment of that seed bank (Harper, 1977). For ecologists and applied biologists, the aspect of greatest significance is the role of the seed bank in determining the future vegetation through the principle of regeneration, especially after natural or deliberate perturbation (Fenner, 1985). The following research was initiated with the objectives of gaining more knowledge on the role of seed banks in stimulating spontaneous vegetation regeneration leading to natural dry evergreen afromontane forest restoration, by analyzing their species composition and abundance and further investigates the difference on soil seed bank in exclosures and the adjacent free grazing areas.

Materials and Methods.

Soil Seed Bank Sampling and Analysis

The data used for this study were collected in 2015 to 2016 in Tigray region form 3 *woredas* which are Raya Azebo *Woreda* (Genete, Hawelti, Mehoni *Kebeles*), Atsbi Womberta *Woreda* (Hadinet, Kelesha Emene, Haikmeshal *Kebeles*), and Kilte Awelaelo *Woreda* (Kihen, Negash, Abreha We Atsbeha *Kebeles*) located in Southern and Eastern parts of Tigray region (Figure 1). The *Kebeles* demonstrate degraded vegetation and soils and differ in elevation, rainfall, agro-ecology, access to the main road, distance to regional capital, population distribution and density and lithology.

Soil seed bank density, diversity, vertical and horizontal distribution and composition were assessed by collecting 360 soil samples (3 successive layers x 90 points in exclosures and 3 successive layers x 30 points in adjacent areas) from 120 quadrants (30 from each age separated) exclosures from all three sites which is 90 and 30 from adjacent free grazing lands from all sites). Methodology following Bakker *et al.*, (Bakker *et al.*, ., 2000), ter Heerdt *et al.*, (ter Heerdt *et al.*, 1996) and Warr *et al.*, (Warr *et al.*, 1993), were collected from quadrants measuring 10 cm x 10 cm (100 cm^2) and each time divided in three sub-samples according to soil depth: 0-3 cm, 3-6 cm and 6-9 cm by using digger and labelled metal rods and carefully removed with afield knife and placed in plastic bags separately. The litter layer was included with the soil samples as 1^{st} layer. Sample depth was determined based on general knowledge on the vertical distribution of plant seeds in the seed bank and mean field soil depth (Siegel and Castellan, 1988; Skoglund, 1992). The samples were taken from five points covering 10 cm x10 cm (one at the center and the other four at the corners) of each 120 sample quadrants. All sub-samples of a plot from these five points were merged into one pooled sub-sample per depth class, as a large number of small samples are preferred over a small number of large samples in order to have a more accurate representation of the seed bank as found in a specific place (Thompson and Grime, 1979; Turner and Corlett, 1996) and in order to reduce variability within the quadrants. The composite sample for each soil layer was again divided into five equal parts of which one was randomly selected for further study.

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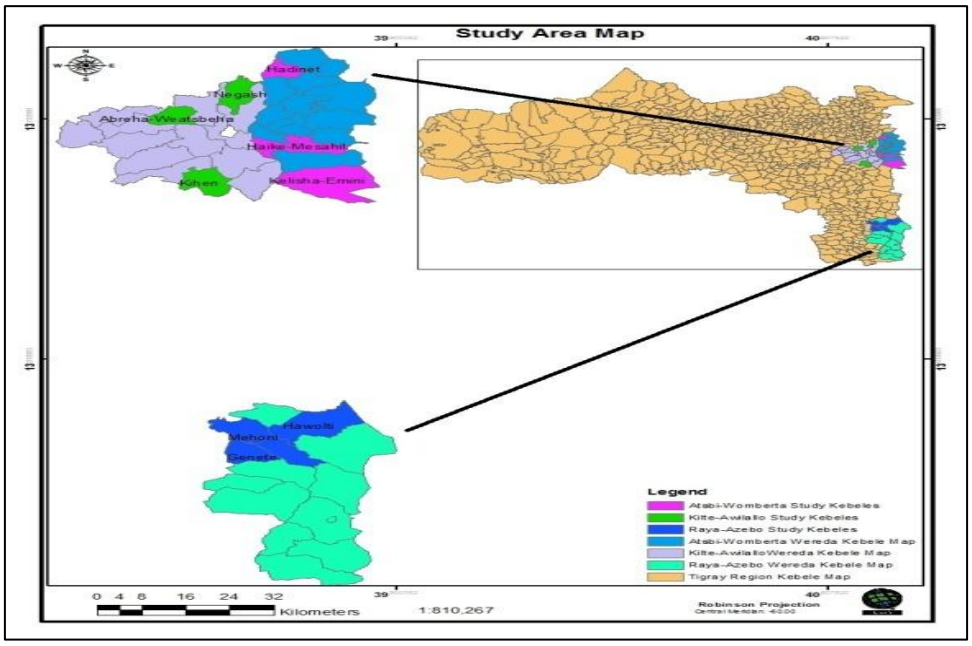

Figure 1. Map of Selected *Kebeles* of the Study areas.

Then persistent seeds in each sample were counted following the methodology used by Getachew *et al.*, (2004). The composite sample for each soil layer was again divided into five equal parts among which one was randomly selected for further study.

Sampling was completed within two weeks to avoid differences between habitats, and thus any temporal bias in seed availability and composition following the method used by Toledo and Ramos (2011). The samples from each soil layer were used to determine variations of seed distribution at each depth of the soil layers (Mulugeta and Demel, 2006). The soil samples were transferred to cotton bags and transported to the greenhouse.

The Soil samples were first sieved (Dainoua *et al.*, 2011) with a mesh size of 2 mm and then using a mesh size of 0.5 mm to recover seeds of various plant species. The recovered seeds were collected into paper bags and taken back to the study area for identification by discussing (asking) with local people and then checked with seeds of the above-ground flora. Internet web pages were also used to know more about the recovered seeds. Once seeds were found and identified, their viability was determined using cutting test/ dissection method following Eyob (2006); and Feyera and Demel (2002) and seeds considered viable when the content of each seed was white and firm (Demel and Granström, 1995).

Since there is no universally accepted maximum duration for a germination test, cutting test is useful for many deeply dormant woody species to check maturity and quality of viable seeds and it was quick and uses low-cost equipment than germination test. Since germination is highly influenced by environmental conditions (temperature, moisture, etc), dormancy breakage of many seeds may not be known, which add difficulty for determination of viability.

Soil samples remained after sieve were spread in small plastic trays and incubated for seed germination in the glasshouse for six months. Tap water was provided regularly in order to allow seed germination. The daily temperature for the glass house ranged from 15-25^{o}C. The emerging seedlings were identified, counted, recorded and discarded. Photo of seedlings was taken to the study area to identify by the local people and confirmed by comparing with the standing vegetation. Seedling recruitment was terminated after 6 months (November 5, 2015, to May 4, 2016). Seedlings that were difficult to identify were transplanted and future identification was taken place at the national herbarium.

The species richness(S) and evenness (E) of soil seed bank composition in each soil profile were analyzed following methodology used by Getachew *et al.*, (2004); and Perera (2005). Jaccard's coefficient of similarity (JCS) was used to analyze the similarity between soil seed bank compositions among other sites (exclosures and free grazing). Variance analysis of species abundance in each soil layer and other sites was done by ANOVA using SPSS software (Version 20). The composition and density of seeds in the soil were determined by combining the data obtained from sieving and germination. The density of seeds was derived from the total number of seeds recovered from the soil samples. On the other hand, to analyze the depth distribution of seeds in each, the number of seeds recovered in similar layers were combined and converted to provide the density of seeds/m^2 at that particular soil depth following methodology used by Getachew *et al.*, (2004); Eyob (2006) and Warr *et al.*, (1993).

Data Collection and Analysis for Soil Physical and Chemical Properties

Data were gathered from 120 quadrants (90 from restorations or exclosures of different ages and 30 from adjacent free grazing lands) for soil analysis. From each quadrant, five soil samples (from a depth of 20 cm) were collected from an area of 2 m × 2 m from each corner and center and mixed to produce a composite soil sample, each weighing 0.7- 1 kg. One core sample was taken for bulk density analysis. The samples were collected from each position were mixed thoroughly in a large bucket to form a composite soil sample resulting in a total number of the whole samples. The soil samples were air dried by spreading on plastic trays, crushed and sieved with a mesh size of 2 mm. The soil samples were analyzed following Juo (1978) and Sahlemedhin and Taye (2000). Procedures like pH with potentiometrically in the supernatant suspension of 1:5 soil: liquid mixture; total nitrogen (N) by the Kjeldahl method, Exchangeable calcium (Ca) and magnesium (Mg) was extracted by ammonium acetate (pH 7) using atomic absorption spectrophotometer, and exchangeable potassium (K) and sodium (Na) by leaching using ammonium acetate (pH 7) using flame photometer and available phosphorus (P) was analyzed by Olsen method. Soil organic carbon, bulk density, and particle size were determined using the Walkley–Black method (Walkley and Black, 1934), the core method (Blake and Hartge 1986) and the hydrometer method (Gee and Bauder 1982) respectively.

Results and Discussions

Composition and Density of Soil Seed Banks

The total numbers of species recovered from the soil samples collected in the study area were 47 for the exclosure and 39 for the free grazing area and totally 62 species (data from germination and sieving combined) (see Table 5). There were no woody species obtained from the soil seed bank, all seeds found were herbs and climbers. The number of SSB species in the free grazing lands and each age exclosure was shown in Figure 2.

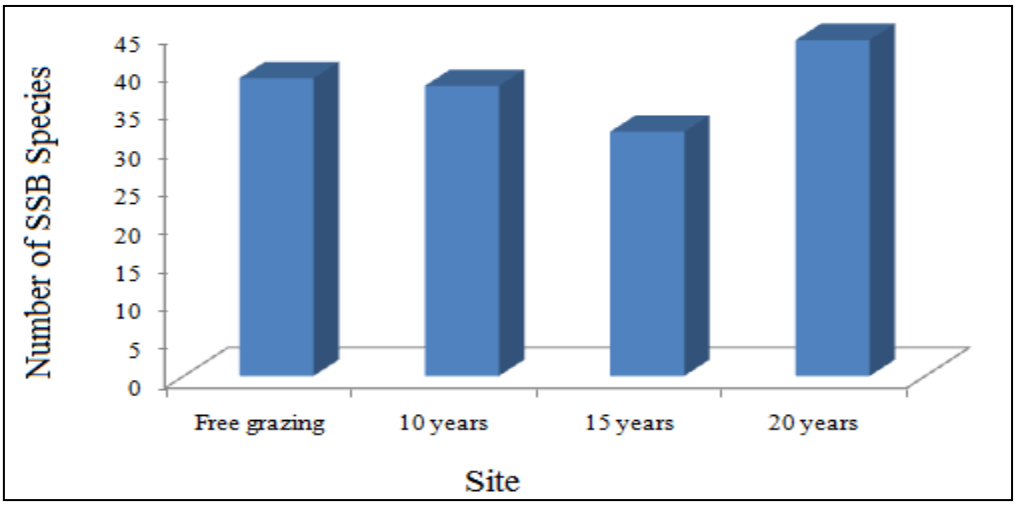

Figure 21. Number of SSB species in each site.

The total numbers of seeds obtained from all soil samples collected down to the depth of 9 cm in the exclosure (total area of samples = 9000cm^2) and free grazing area (total area of samples = 3000cm^2) were 47 and 39, respectively. These corresponded to mean densities of 1868 and 1431 seeds m^{-2}, respectively. The highest densities of seeds were observed in the upper three centimeters of soil in both the exclosures and free grazing areas and seed density decreased with increasing depth (Figure 4).

Similarity in Species Composition among Exclosures and free Grazing Areas

The similarity in species composition of the soil seed bank between the different age exclosures and free grazing areas was generally average and ranged from JCS values of 0.2 to 0.56 (between free grazing vs. 15 years exclosure and 15 years vs. 20 years exclosure). The second highest similarity in species composition (*Sj* = 0.53) was recorded between 10 years and 20 years exclosure (Table 1).

Similarity of Soil Seed Bank and Above-Ground Flora

The similarity between the soil seed bank and above-ground flora was also low for exclosures *Sj* value 0.29 and average for free grazing area *Sj* value 0.51 (Table 1). But the herbs similarities was high showing 0.75 and 0.78 similarities in exclosures and free grazing respectively.

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Table 11. Jaccard's coefficient of similarity in species composition of soil seed banks between the differently aged exclosures and free grazing areas.

	Free grazing	10 Years Exclosure	15 Years Exclosure	20 Years Exclosure
Free grazing	*	0.34	0.20	0.33
10 Years Exclosure		*	0.52	0.53
15 Years Exclosure			*	0.56
20 Years Exclosure				*

Species Density of Soil Seed bank (SSB) Flora in the Study Sites

The total seed density in the upper nine centimeters both from seedling emergence and seed counting method was 1868 seeds m^{-2} for exclosures and 1431 seeds m^{-2} for free grazing areas. This result showed considerably higher density in 10 years exclosure and generally higher in exclosures than free grazing lands (Figure 3).

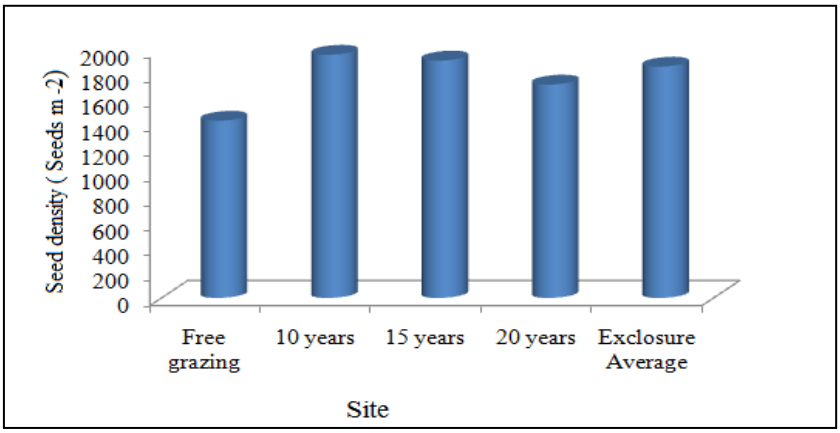

Figure 3. Seed density of SSB in each site.

Distribution of Seeds in Soil Layers

The maximum viable seed density was recorded in the first sampling layer 0-3 cm for all sites (exclosures of different ages and free grazing areas (Figure 4). The total seed bank density decrease as the soil layer depth increase. In exclosures, the seed density was 1107 seeds m^{-2}, 553 seeds m^{-2} and 208 seeds m^{-2} in 0-3cm, 3-6cm and 6-9 cm soil layers respectively, while in free grazing it was 951 seeds m^{-2}, 436 seeds m^{-2} and 44 seeds m^{-2} in 0-3cm, 3-6cm and 6-9 cm soil layers respectively (Figure 4).

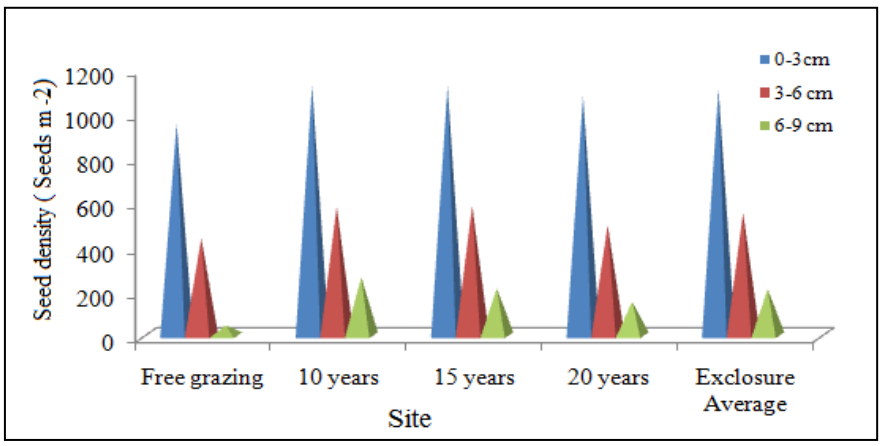

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Figure 4. Seed density of SSB at a different layer in each site.

Densities of seeds in the soil layer collected from all ages of exclosures and free grazing lands showed significant differences [one way ANOVA: P<0.05]. Similarly a smaller amount of seeds found within the 6-9 cm depth as compared to 3 to 6 cm depth.

Species Richness, Diversity and Evenness of Soil Seed bank (SSB) Flora

The Shannon diversity index demonstrated high value for the diversity of SSB in all exclosure ages and free grazing areas. In the same way, the Shannon evenness index (E) had also almost consistence value among all exclosure ages and free grazing areas (Table 2).

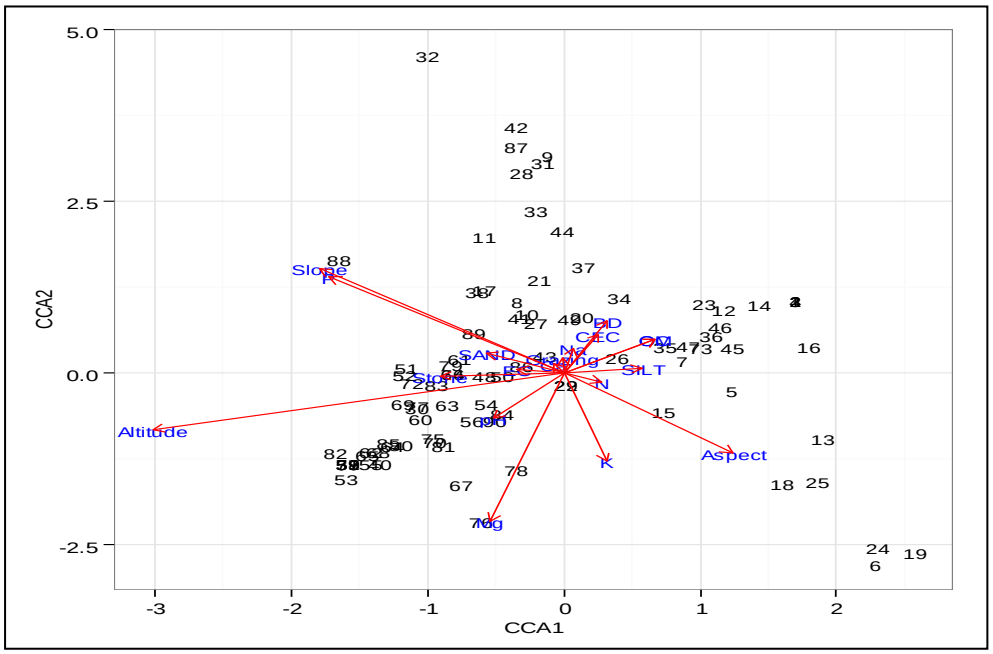
Table 2. Species diversity, richness and evenness of the SSB in exclosures and free grazing areas

		Richness	H	Evenness
	Free grazing	39	3.36	0.84
Exclosure	10 years	38	3.36	0.82
	15 years	32	3.34	0.87
	20 years	44	3.41	0.86

Aggregation of Environmental Variables in SSB of Exclosures and free Grazing Lands.

Results for permutation test sequentially for CCA under reduced model marginal effects of terms (Table 3); results of ANOVA and CCA test for the availability of axes (Table 4) for the SSB of exclosures and free grazing lands. Additionally a range of possible environmental variables such as altitude, aspect, slope, grazing and disturbance, Stoniness and major soil parameters like (Sand, Silt, Clay, PH, EC, Na, OM, CEC, Mg, Ca, K, N, P, BD and OC) were analyzed and presumed to by ordination graph for both exclosures and free grazing areas (Figures 5 Aand B) were given below.

A.Exclosure



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B.Free grazing

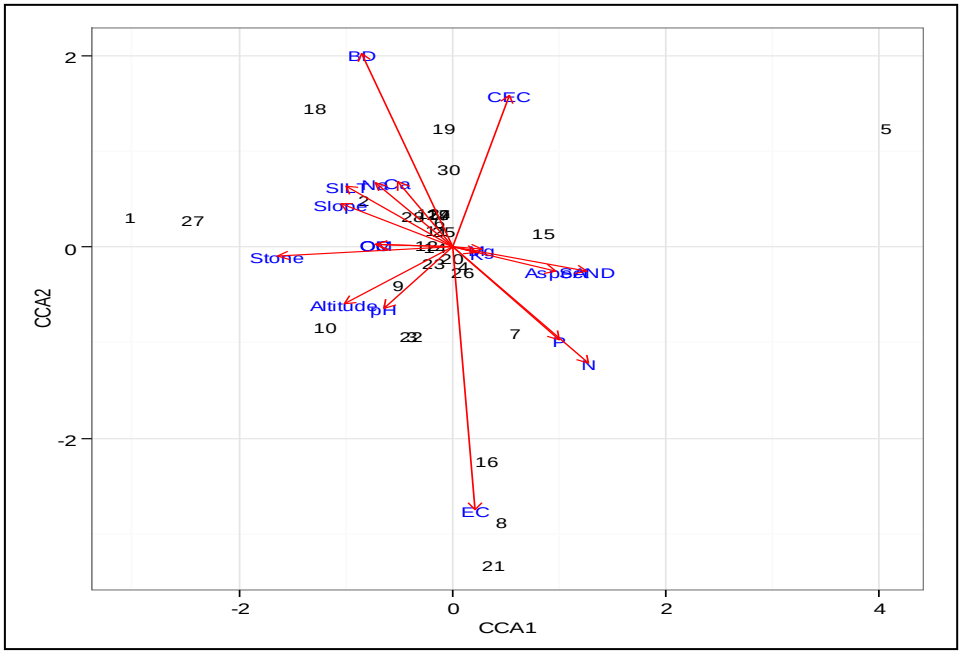

Figure 5 A and B. CCA: Displaying sites constrained by environmental factors for SSB.

The total numbers of species recovered from the soil samples collected in the study area were 47 for the exclosure and 39 for the free grazing area and totally 62 (See table 5). There were no woody species obtained from the soil seed bank, all seeds found were herbaceous. There is also a very low number of woody species in studies made in the northern part of Ethiopia by Tefera (2001), Kebrom and Tesfaye (2000) and Kebrom (2001) as compared to other areas studied in Afromontane and rift valley biotopes by Demel (1997), Feyera (1998) and Mekuria *et al.*, (1999). The lack of woody seeds could be related to the high level of degradation and erosion in the northernmost part of the country, as the seed bank density is negatively affected by erosion (Bergston, 1993; Granström, 1986). Woody plants generally have low seed numbers (Demel and Granstrom, 1995) and are short-lived in the soil (Demel, 1997). Instead, most woody seeds germinate soon after rain indicating that they rely on a seedling bank. This is a common regeneration strategy probably appropriate for tropical woody species as seed losses can be expected for many reasons (Jerry, 1992). *Acacia etbaica* sets its seeds in line with the rainy season and seems to have a strategy of a seedling bank rather than a seed bank. The reason why no seeds were found in the soil seed bank either for the dominant species *Acacia etbaica* or the other woody species in the exclosure could be that the soil seed bank was collected after a year of recurrent drought in the area during the study for the past 2 consecutive years in 2013 and 2014 before the study periods. For the free grazing areas, a lack of seedlings is probably not due to a lack of seeds, it is more likely that they disappear after germination through grazing and trampling. There are probably also other reasons why seeds can be missing like predation. Loss of *Acacia* seeds through predation was reported by (Leck *et al.*, 1989). High seed number of herbaceous and grass species both in the exclosure and the free grazing area may link to a prolonged dry season, which helps with the accumulation of dormant seeds.

The total seed density in the upper nine centimeters both from seedling emergence and seed counting method was 1868 seeds m^{-2} for exclosures and 1431 seeds m^{-2} for free grazing areas. That is comparable with investigations in dry tropical ecosystems that have revealed 48-1890 seeds m^{-2} (Garwood, 1989) and 8-67 species. The lower densities are found in drier areas.

The density of species decreased with depth in both land uses. High seed density in the upper portion of the soil seed bank indicates that the contribution of the standing vegetation is recent since seeds in the superficial layer can be assumed to form part of that season's seed input (Lyarru, 1996). It is interesting and cannot be easily explained why the soil seed bank in the two land-uses was almost the same and at the same time, the ground cover of herbs differed substantially between the two land-uses.

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Table 3. Results of ANOVA.CCA values for marginal effects of environmental variables of SSB for exclosures and free grazing area.

	Exclosures							Free grazing					
	Df	Chisq	F	N.Perm	Pr(>F)	Sig. Codes		Df	Chisq	F	N.Perm	Pr(>F)	Sig. Coes
Slope	1	0.15	1.13	99	0.3		Slope	1	0.35	0.91	99	0.5	
Aspect	1	0.11	0.83	99	0.73		Aspect	1	0.32	0.84	99	0.71	
Grazing	1	0.15	1.11	99	0.27		Grazing	0	0.00	0.00	0		
Altitude	1	0.29	2.16	199	0.005	**	Altitude	1	0.44	1.15	99	0.23	
pH	1	0.09	0.71	99	0.85		pH	1	0.29	0.76	99	0.63	
EC	1	0.12	0.92	99	0.48		EC	1	0.38	1.00	99	0.38	
Na	1	0.13	0.98	99	0.42		Na	1	0.39	1.01	99	0.44	
OM	1	0.12	0.89	99	0.67		OM	1	0.47	1.23	99	0.15	
CEC	1	0.15	1.14	99	0.29		CEC	1	0.29	0.74	99	0.62	
Mg	1	0.17	1.24	99	0.13		Mg	1	0.26	0.68	99	0.71	
Ca	1	0.16	1.16	99	0.31		Ca	1	0.47	1.24	99	0.16	
K	1	0.11	0.84	99	0.76		K	1	0.26	0.68	99	0.81	
N	1	0.12	0.83	99	0.71		N	1	0.37	0.96	99	0.42	
P	1	0.18	1.37	299	0.093	.	P	1	0.29	0.76	99	0.68	
Residual	73	9.79					Residual	14	5.37				

Signif. codes: 0 '*' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1**

The diversity of the seeds in the 20 years exclosure is higher (Shannon's H' = 3.41) than the free grazing area as well 10 years and 15 years exclosure. The diversity decreases with depth in both land uses. The similarity of the seed bank between the two land uses is higher than the similarity between the standing vegetation of exclosure and free grazing area. The similarities in species diversity of herbaceous species soil seed banks between the exclosed and free grazing area and the high level of similarity index between the standing vegetation in the exclosure indicate that the free grazing area, if closed, still has a chance to rehabilitate in the same way as the closed area.

Even though no woody species were found in the exclosures and free grazing area, the possible contribution of the soil seed bank for the process of regeneration shouldn't be ruled out (Kebrom, 2001). The high number of herbaceous and grass species found through sieving and incubation from the seed bank shows its role in providing vegetative protection cover that could help in reducing degradation through erosion. For successful woody vegetation reestablishment, however, the seed and seedling banks may require the supplementary planting of seedlings (Kebrom and Tesfaye, 2000).

The landscape in the study area is strongly affected by a high pressure on the natural resources leading to soil degradation, erosion and a severe decline of natural vegetation (Nyssen *et al.*, 2000). Degradation is most severe where land uses impact as evidenced by whether it is exclosure or free grazing land and where soils are naturally nutrient-poor.

Nutrient-poor and disturbed ecosystems are characterized by species-rich aboveground vegetation, mainly consisting of herbs, in contrast with the undisturbed ecosystems that are dominated by a limited number of woody species.

Following Gray and Megahan (Gray and Megahan, 1981), the role of vegetation in erosion control can be attributed to (a) the umbrella or shield effect, as vegetation breaks the impact of raindrops before they hit the soil; (b) surface flow retardation; (c) regulation of soil moisture content and piezometric levels through transpiration and interception; and (d) root reinforcement through buttressing, anchorage and soil reinforcement. The first factor is mainly determined by permanence/absence of vegetation over the different seasons and by the foliar cover, i.e. the area of ground covered by the vertical projection of the aerial portions of the plants. As evidenced in this study, vegetation in the free grazing areas is species-rich, but its composition is greatly dominated by grasses, herbs and a few low shrubs and sparsely found limited big trees. Herbaceous cover is low in these cases, as leaf area is limited, and raindrop impact is, therefore, bigger, leading to higher erosion risk. This effect is aggravated by a drastic decrease in foliar cover during the dry season, with most severe raindrop impact at the start of the rainy season as result. This is in contrast to undisturbed, water and nutrient-rich forest relics and exclosures with higher ages, where a permanent canopy is present. Between these two extremes, many intermediate situations occur.

Table 4. Results of ANOVA. CCA test for the availability of axes for SSB in exclosures and free grazing area.

		Exclosure						**Free grazing**				
	Df	Chisq	F	N. Perm	Pr(>F)	Sig.	Df	Chisq	F	N. Perm	Pr(>F)	Sig.
CCA1	1	0.51	3.79	199	0.01	**	1	0.80	2.09	199	0.02	*
CCA2	1	0.30	2.27	199	0.01	**	1	0.75	1.95	199	0.02	*
CCA3	1	0.25	1.87	199	0.01	**	1	0.62	1.63	899	0.03	*
CCA4	1	0.22	1.63	399	0.03	*	1	0.58	1.52	999	0.06	.
CCA5	1	0.20	1.47	599	0.08	.	1	0.54	1.42	99	0.13	
CCA6	1	0.16	1.19	99	0.22		1	0.45	1.18	99	0.23	
CCA7	1	0.14	1.01	99	0.51		1	0.34	0.89	99	0.47	
CCA8	1	0.12	0.93	99	0.55		1	0.31	0.81	99	0.59	
CCA9	1	0.08	0.62	99	0.96		1	0.24	0.62	99	0.80	
CCA10	1	0.07	0.55	99	1.00		1	0.20	0.51	99	0.89	
CCA11	1	0.07	0.53	99	0.99		1	0.15	0.40	99	0.99	
CCA12	1	0.06	0.44	99	1		1	0.12	0.31	99	1	
CCA13	1	0.05	0.36	99	1		1	0.08	0.21	99	1	
CCA14	1	0.04	0.26	99	1		1	0.05	0.12	99	1	
CCA15	1	0.03	0.25	99	1		1	0.03	0.08	99	1	
CCA16	1	0.02	0.17	99	1							
Residual	73	9.80					14	5.37				

Signif. codes: 0 '*' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1**

Results from correlation analyses between seed bank data and environmental data ordination (Figures 5 A and B) and correlation analysis of ordination scores indicate that seed density and seed bank composition are mostly explained by soil nutrient status and altitude. The land uses type, although a somewhat subjective oversimplification of the land degradation processes seems to offer a valuable indicator approach, which merits further development. It will, however, need validation and further use and development before it will become a mainstream parameter. In free grazing areas, vegetation density and foliar cover decrease, whereas soil compaction and soil particle detachment are expected to increase. This leads to a higher erosion risk. In erosion-prone areas, topsoil, where most of the seed bank can be found, is washed away. As a consequence, a significant part of the seed bank is simply transported downslope.

The remaining soil is shallow with high stoniness, leading to limited soil volume for seed bank development and recruitment. Therefore, one could have expected a negative correlation between seed density and stoniness. Although this trend is visible in our research, we were not able to evidence it through a significant statistical relation.

Seed density in seed banks was higher under exclosures than free grazing areas in the research area. In contrast to most tropical rainforests, dry lowland forests, and savannas, where both the number of seeds and the number of species are relatively small, dry Afro-montane forests store large quantities of seed in the soil (Demel and Granström, 1995). Another contrast of dry Afro-montane forest with the former is the dominance of herbs in its seed banks (Demel and Granström, 1995), a characteristic also typical of seed banks in temperate zones (Bossuyt and Hermy, 2001). Instead of developing seed bank reserves, Afro-montane tree species usually form seedling banks on the forest floor (Demel, 1997). The lack of germination of woody species is probably related to their bigger seed size: small and compact seeds tend to persist in the soil for a longer time than big and elongated or flattened seeds. This is mainly because large seeds are less likely to be incorporated into the soil as they have less chance of finding their way passively down cracks in the soil or being buried by soil organisms, and because they are more prone to predation and fungal infection (Bakker *et al.*, 2000).

In the research area, possibilities of natural restoration by species germinating from the seed bank are limited, because of the overall lack of forest climax species in the seed bank since the area is not a forest area. The development of understory vegetation consisting of herbs after disturbance, however, is to be expected and can play an important role in the regulation of water and nutrient balances, production of organic material and maybe an even limitation of erosion. In that way, some important conditions for full recovery are fulfilled.

On the other hand, competition for space, nutrients, and water is to be expected, thus preventing the development of species important for natural regeneration. To gain more knowledge on these processes, further research on community ecology, to understand the interactions between species present within the community, is necessary. Also, the effect of environmental conditions on seed bank characteristics should be studied more thoroughly. This research demonstrates that seed banks in the study area mainly consist of herbs and climbers. Clearing of forest relics followed by intensive grazing and browsing or permanent cultivation would, therefore, result in a replacement of nearly all woody components by a set of herbaceous species from the soil seed bank (Demel, 1997). As a consequence, successful natural forest rehabilitation would primarily depend on the availability of seed trees in the vicinity and seed dispersal by birds and other vectors. This underlines the importance of sustainable managing the few remaining forest relics and relic trees (Turner and Corlett, 1996). These islands of biodiversity in a sea of degraded landscapes are the key factor for natural forest rehabilitation (Turner and Corlett, 1996) and the most urgent issue at this moment is their conservation (Janzen, 1988).

Conclusion and recommendations

Participation by local communities is the foundation for the success of projects aiming at discouraging further environmental degradation and deforestation. The complex problems in which lack of water, wood, and land have a central place, have to be dealt with in an integrated way, taking into account local knowledge and needs. Similarity between the soil seed banks and aboveground flora was very low implying that the role of soil seed banks in the regeneration is low and dispersal of seeds from the adjacent forest areas play an important role in the process. These results support the idea that assisted natural regeneration can promote the regeneration of species and increase plant biodiversity in the area after exclosures established. It is also recommend that more research should be carried out for better understanding of the successsional processes within exclosure establishment and restorations of an area such as the dynamics of seed germination, seed dispersal, seed predation as well as seedling establishment and growth. It is also necessary to investigate how the established plant species can be manipulated to develop in to a secondary forest.

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Table 5. List of identified species family and habits from the SSB of exclosures and free grazing areas

Exclosure			Free grazing		
Species	**Family**	**Life Form***	**Species**	**Family**	**Life Form***
***Achyranthes aspera* L.**	Amaranthaceae	H	*Achyranthes aspera* L.	Amaranthaceae	H
***Aerva lanata* (L.) Juss. ex Schultes**	Amaranthaceae	H	*Aerva lanata* (L.) Juss. ex Schultes	Amaranthaceae	H
***Argemone Mexicana* L.**	Papaveraceae	H	*Argemone mexicana* L.	Papaveraceae	H
***Asparagus racemosus* Willd.**	Asparagaceae	H/C	*Asparagus racemosus* Willd.	Asparagaceae	H/C
***Bidens pilosa* L.**	Acanthaceae	H	*Bidens pilosa* L.	Acanthaceae	H
***Cissus quadrangularis* L.**	Vitaceae	C	*Chenopodium murale* L.	Chenopodiaceae	H
***Clematis simensis* Fresen.**	Ranunculaceae	C	*Cissus quadrangularis* L.	Vitaceae	C
***Datura stramonium* L.**	Solanaceae	H	*Clematis simensis* Fresen.	Ranunculaceae	C
***Digitaria abyssinica* (Hochest.ex A. Rich.) Stapf.**	Poaceae	H	*Cynodon dactylon* (L.) Pers.	Poaceae	H
***Eragrostis papposa* (Roem. & Schult.) Steud.**	Poaceae	H	*Datura stramonium* L.	Solanaceae	H
***Eragrostis tenuifolia* (A. Rich.) Steud.**	Poaceae	H	*Digitaria abyssinica* (Hochest.ex A. Rich.) Stapf.	Poaceae	H
***Galium spurium* L.**	Rubiaceae	H	*Eragrostis papposa* (Roem. & Schult.) Steud.	Poaceae	H
***Glycine wightii* (Wight & Arn.) Verdc.**	Fabaceae	C	*Eragrostis tenuifolia* (A. Rich.) Steud.	Poaceae	H
***Hibiscus ovalifolius* (Forssk.) Vahl**	Malvaceae	H	*Euphorbia petitiana* A. Rich	Euphorbiaceae	H
***Hyparrhenia hirta* (L.) Stapf**	Poaceae	H	*Galium spurium* L.	Rubiaceae	H
***Indigofera hochstetteri* Bak.**	Fabaceae	H	*Glycine wightii* (Wight & Arn.) Verdc.	Fabaceae	C
***Ipomoea sinensis* (Desr.) Choisy**	Convolvulaceae	C	*Helinus mystacinus* (Ait.) E. mey. ex Steud	Rhamnaceae	C
Jasminum dichotomum	Oleaceae	C	*Hibiscus ovalifolius*	Malvaceae	H

Vahl			(Forssk.) Vahl		
***Kalanchoe lanceolata* (Forssk.) Pers.**	Crassulaceae	H	*Hyparrhenia hirta* (L.) Stapf	Poaceae	H
***Laggera tomentosa* (Sch. Bip. ex. A. Rich.) Oliv. & Hiern**	Asteraceae	H	*Hypoestes forskaolii* (Vahl) R.Br.	Acanthaceae	H
***Lepidium bonariense* L.**	Brassicaceae	H	*Indigofera hochstetteri* Bak.	Fabaceae	H
***Leucas abyssinica* (Benth.) Briq.**	Lamiaceae	H	*Ipomoea sinensis* (Desr.) Choisy	Convolvulaceae	C
***Malva verticillata* L.**	Malvaceae	H	*Jasminum dichotomum* Vahl	Oleaceae	C
***Mentha longifolia* (L.) Hudson**	Lamiaceae	H	*Kalanchoe lanceolata* (Forssk.) Pers.	Crassulaceae	H
***Ocimum urticifolium* Roth**	Lamiaceae	H	*Kalanchoe marmorata* Bak.	Crassulaceae	H
***Oxalis corniculata* L.**	Oxalidaceae	H	*Laggera tomentosa* (Sch. Bip. ex. A. Rich.) Oliv. & Hiern	Asteraceae	H
***Oxygonum sinuatum* (Meisn.) Dammer**	Polygonaceae	H	*Lepidium bonariense* L.	Brassicaceae	H
***Panicum maximum* Jacq.**	Poaceae	H	*Leucas abyssinica* (Benth.) Briq.	Lamiaceae	H
***Parthenium hysterophorus* L.**	Acanthaceae	H	*Malva verticillata* L.	Malvaceae	H
***Pennisetum unisetum* (Nees.)Benth.**	Poaceae	H	*Medicago polymorpha* L.	Fabaceae	H
***Phagnalon abyssinicum* Sch. Bip. ex A. Rich.**	Asteraceae	H	*Mentha longifolia* (L.) Hudson	Lamiaceae	H
***Poa leptoclada* Hochst. ex A. Rich.**	Poaceae	H	*Orobanche ramosa* L.	Orobanchaceae	H
***Polygala obtusissima* Chod.**	Polygalaceae	C	*Osteospermum vailliantii* (Decne.) T.Norl.	Asteraceae	H
***Rumex abyssinicus* Jacq.**	Polygonaceae	H	*Pennisetum sphacelatum* (Nees) Th. Dur.& Schinz	Poaceae	H
***Rumex nervosus* Vahl.**	Polygonaceae	H	*Rhynchosia elegans* A. Rich.	Fabaceae	H
***Satureja punctata* (Benth.) Briq.**	Lamiaceae	H	*Silene burchellii* DC.	Caryophyllaceae	H

***Solanum incanum* L.**	Solanaceae	H	*Tephrosia uniflora* Pers.	Fabaceae	H
***Solanum nigrum* L.**	Solanaceae	H	*Urtica simensis* Steudel.	Urticaceae	H
***Solanum schimperianum* Hochst. ex A.Rich.**	Solanaceae	H	*Veronica anagalis-aquatica L.*	Scrophulariaceae	H
***Sonchus oleraceus* L.**	Asteraceae	H	*Note**		
***Sporobolus pyramidalis* P. Beauv.**	Poaceae	H	H- Herb C- Climber		
***Tagetes minuta* L.**	Asteraceae	H			
***Trifolium baccarinii* Chiov.**	Fabaceae	H			
***Trifolium rueppellianum* Fres.**	Fabaceae	H			
***Verbascum sinaiticum* Benth.**	Scrophulariaceae	H			
***Vigna membranacea* A. Rich.**	Fabaceae	C			
***Withania somnifera* (L.) Dunal**	Solanaceae	H			

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